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Web caching in school districts

Caching on E-rate continues to help districts reach internet speed and affordability targets

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Contents

1. Introduction

This report details the findings of ApplianSys' research into the impact of caching on the cost and efficacy of US school district internet access. These findings will be presented in face-to-face meetings between ApplianSys Head of Education Technologies, Roger Clark, and representatives of FCC Commissioners and officers of FCC's Wireline Competition Bureau, November 2018. Source data will be provided electronically and included in ex-parte submission for visibility and comment.

In 2017, ApplianSys brought to the FCC's attention the positive network performance of caching within the E-rate program - how its effect was beyond original expectation, not just on bandwidth savings but also speeding up web content and protecting it from software update spikes, helping schools secure the most effective learning experience in the classroom.

As part of the 2017 submissions, ApplianSys explained, with evidence from schools' networks, why caching delivers the performance benefits that is does in K12:

- Peak demand for online content in schools is typically more than 7 times average demand
  - Traffic spikes consist of repeat requests for identical content
  - To avoid congestion, schools, and the organizations that advise them, base capacity requirements on these short but troublesome traffic spikes
  - Catering for peaks with bandwidth alone is wasteful
- Purchasing sufficient capacity to avoid congestion does not guarantee fast access to content
  - Large software update files download at low speed even through high-capacity connections
    - Congestion caused by this is exacerbated by the growing volume of devices in schools
- Caching take-up on E-rate has been low to date, with outdated perceptions of the technology as expensive, ineffective and difficult to manage
  - ApplianSys delivered traffic and cost analysis at districts with caches to show how the technology delivers faster content at lower cost than bandwidth alone

Following these meetings, ApplianSys agreed to undertake further research and analysis to extrapolate beyond this performance data and identify the *impact* of that caching performance, considering each of: the classroom; technology team workflows; cost reduction through slowing both infrastructure and link upgrade cycles.

Having now completed this analysis, we can report that:

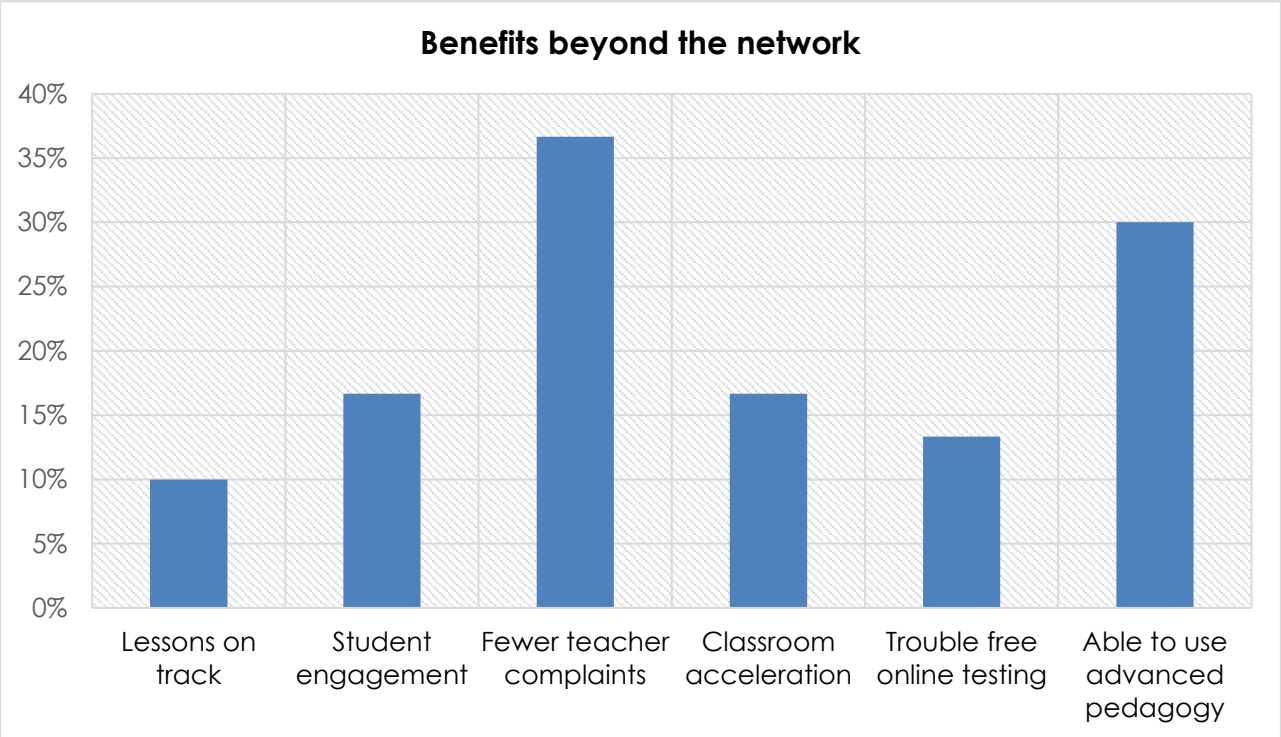
1. For schools that deploy caches, the Return on Investment goes well beyond financial savings
2. Caching performance remains high in school districts... and is improving
3. Awareness of caching is low, and this is reflected in the number of districts that take it up
4. Ubiquitous caching would save hundreds of millions of dollars each year.

2. Research findings

Throughout 2018 ApplianSys has undertaken telephone and online surveys, recorded customer experiences and directly analyzed detailed customer data in order to deliver the detail and insight the FCC are looking for.

2.1 Finding one: For schools that deploy caches, the Return on Investment goes well beyond financial savings

Last year we told you how caching helps districts to overcome congestion and sub-optimal web access speeds even on multi-gigabit connections. Now we can elaborate on those network-level performance improvements with evidence of the broader impact. ApplianSys asked its **CACHE**BOX customers to describe the impact that caching has had in their district.



Technology Directors were unsurprisingly pleased with a reduction in teachers complaining about internet performance in class. Many were able to give us more details about what that specifically meant, listing:

- An increased ability to use modern teaching methods and tools
- Better engaged students
- Lesson plans remaining on track.

Pinch-points like Online Testing were trouble-free, in most cases for the first time since such testing was introduced. A sample of comments received follows, with a complete set available in the full report. The comments highlight the direct relationship between reducing congestion and speeding up content with caches and the ability of teachers and students to benefit from web access as intended.

Category	Comments	Sample comment
Lessons on track	3	"Teachers able to do stuff without worrying about lag from student to student." **Marshall Graham, Tech Director, Carl Junction, MO**
Student Engagement	5	"Students upload and share content via the district website - before **CACHE**BOX was put in, it was far too slow to be usable. Now, students and teachers can use it much more easily" **Bryan Ruff, IT Director, Emmetsburg High School, IA**
Fewer Teacher Complaints	12	"Complaints stopped, things are faster. Less busy work for me and more real work." **Aaron Gurul, Director of Technology, Airport Community**
Classroom Acceleration	4	"When we turned our box off for a day, our network slowed down and teachers noticed." **Greg Harman, Nueces Canyon, TX**
Trouble Free online testing	4	"This is the first year that they have gone through online testing season without any stoppages or challenges." **James Caudell, Network Administrator, Blanco ISD, TX**
Able to use modern pedagogy	9	"Teachers are happy and students have free access to video based independent learning for the first time" **Fadil Hamidovic, Bayless School District, MO**

All comments received are available in Appendix A: Return on Investment Comments

2.2 Finding two: Caching continues to deliver…

With caching appliances installed across more than 40 states, ApplianSys has accumulated detailed and aggregated performance data, as well as critical observations from customers both new to caching, as well as long-time users.

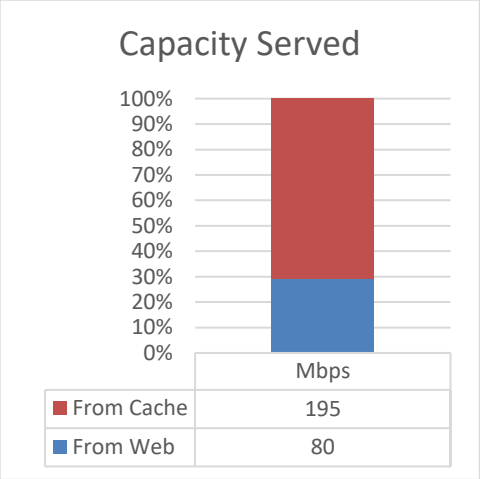
We can report that caching in US schools continues to:

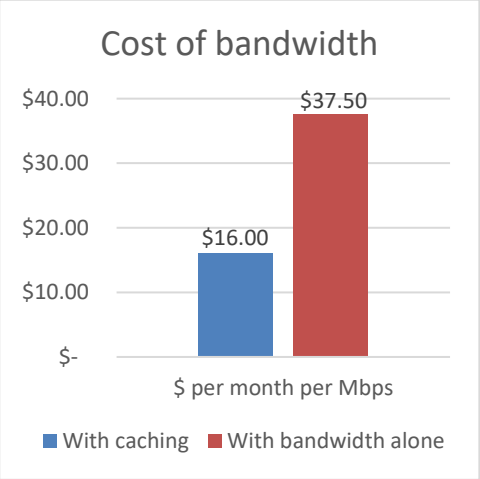
- Lower a school's bandwidth usage, effectively reducing the need for more broadband spend
- Enable schools to do more with less bandwidth by multiplying effective capacity, as much as 10 times
- Slow the rate at which schools need to renew infrastructure.

Our recent data analysis has revealed new evidence that shows even better performance figures than last year, for all districts – rural, suburban or urban. We illustrate these benefits with some examples below and provide many more in *Appendix B: School District Caching Profiles*.

Southwest Barry Community School District R5 is an 800-student district in rural south west MO that pays $3000 per month for an 80Mbps internet connection.

The district deployed caching in 2015 and now benefits from the equivalent of 275Mbps at a far better price per Mbps.



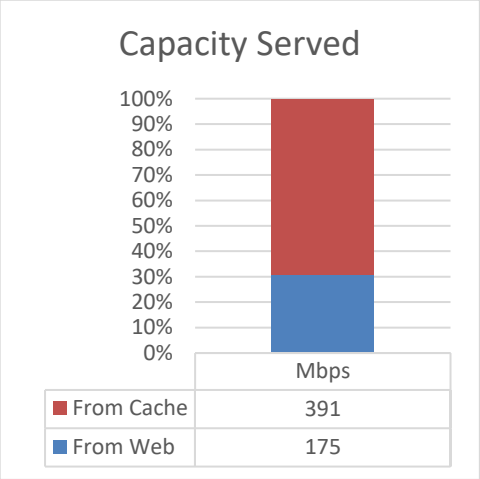


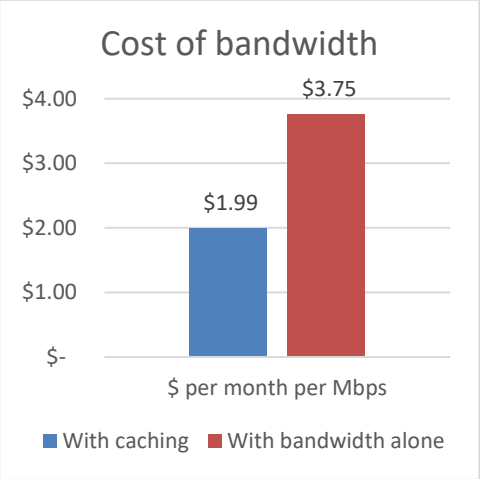
*Cost of bandwidth is {monthly cost/capacity}. To calculate the 'with caching' cost, a 5 year actualized price of **CACHE**BOX is added to the monthly cost, and the virtual capacity delivered by **CACHE**BOX is added to capacity. In this case the calculation is {($3000+$120.49)/275Mbps = $16}*

*Capacity served shows the highest traffic peaks (i.e. the genuine bandwidth required) seen within the district and splits those requests served from cache and those from the internet connection itself. In this case, the traffic at peak times was 275Mbps with 80Mbps of requests s erved from the connection and the rest from **CACHE**BOX.*

"Video has been a long-standing challenge for our teachers. We have been a school wide deployment for media library for all our teachers to use and issued training materials for them with department leads."
Dan Shelton, Technology Director

Orient-Macksburg Community School District serves 160 students in rural Iowa. The district pays $656 per month for 175Mbps much of which was being consumed by software updates. Caching has significantly reduced this duplicate content and delivers update files much faster, clearing the network for other content.





"We can now use the online learning platforms the district purchases like Apex learning. We can live with what we have and not hear complaints. Since we had it, network software updates are not killing our speed. Biggest impact has been speed in all aspects."

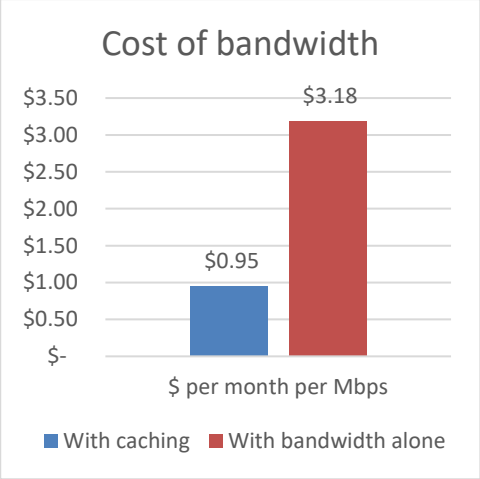
Andrew Rothe, IT Manager

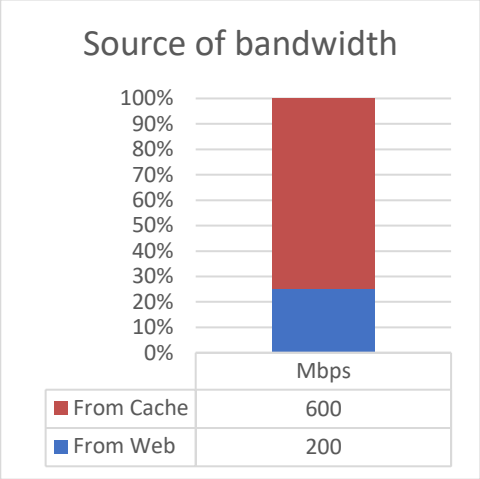
Software vendor	Volume served from cache	Speed increase from cache
Windows	42%,	20x
Apple	42%,	22x
Google	75%	4x
Microsoft	64%	35x

*Orient Macksburgh **CACHE**BOX Report*

East Peoria High School District in Illinois benefits from its urban location, paying $1,865 for 500Mbps to serve 1005 students. This gives it nearly 500Kbps per student for a very reasonable $3.75 per Mbps. But the same benefits apply as at its rural counterparts.

Peaks in demand – now served by **CACHE**BOX - are significantly higher than the 500Mbps link capacity, revealing the true bandwidth requirement at the district as 1,300Mbps. In other words, if the District didn't have the caching solution and instead relied solely on bandwidth to provide sufficient capacity to avoid congestion, the District would need a 1,300Mbps connection. Caching has given East Peoria the total effective capacity it needs at less than half the FCC affordability target ($5.50 at 500Mbps).

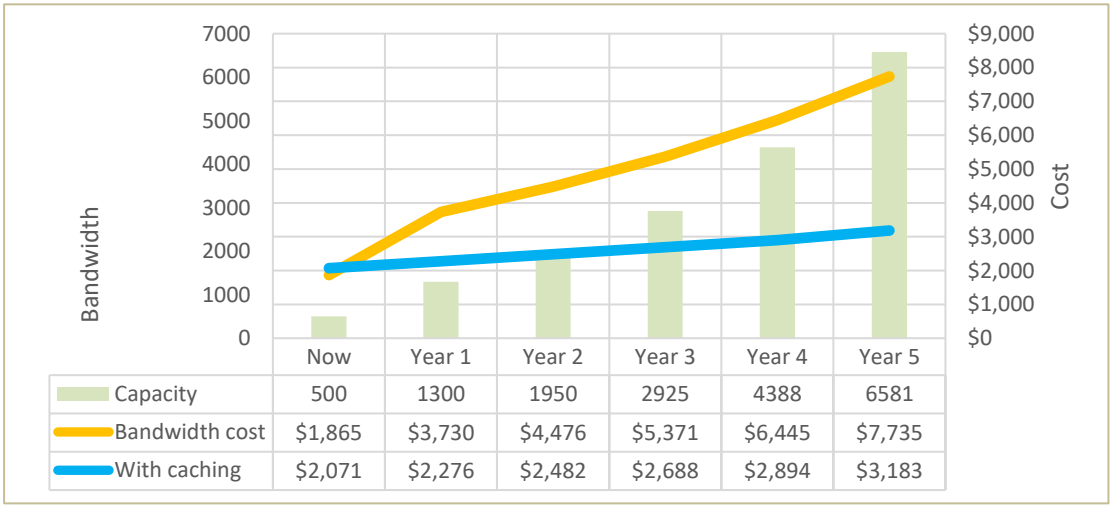




"Our apexlearning classes are for challenging high school students, classroom management, learning struggles. Having a reliably fast connection helps manage these students, and help them reach graduation."

Paul Stanford, Network Administrator

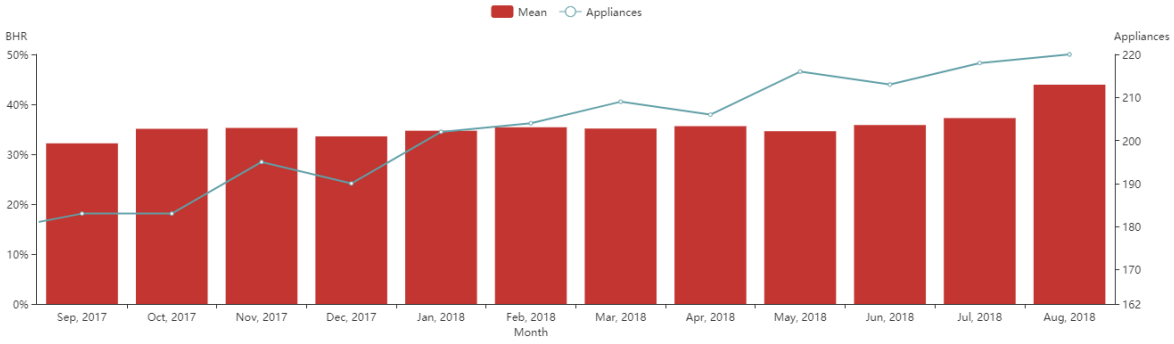
Delivering the 1300Mbps that East Peoria needs now with a large bandwidth upgrade and then catering for 50% year-on-year growth with bandwidth alone would cost $168k more over 5 years than augmenting bandwidth investments with caching.



The Proportion of school content being cached is growing

ApplianSys has enhanced its capability for reporting performance data from US schools – named and anonymous. The aggregated results reflect an ongoing trend in improved appliance performance, which is due to ApplianSys engineers responding to changes in school traffic profiles - improving caching performance through regular **CACHE**BOX updates. **CACHE**BOXes are caching a growing proportion of content, month by month, including problematic files and secure HTTPS content.

Schools' appliances can provide anonymized 'phone home' data to the ApplianSys cloud performance monitoring service and the number of devices utilizing this service has increased by 20% from September 2017 to July 2018. In the same period, the proportion of data being served locally by these **CACHE**BOXes has grown by over 15% - from a 32.2% Byte Hit Ratio (BHR - the ratio of bytes served by the cache over the total number of bytes requested by the clients) to 37.2%.



Mean BHR	32.2%	35.1%	35.3%	33.6%	34.7%	35.4%	35.1%	35.6%	34.6%	35.8%	37.2%	43.9%
Median BHR	32.8%	37.1%	36.2%	34.1%	34.8%	35.6%	34.7%	36.2%	37.2%	35.8%	37.3%	45.9%
No. of Appliances	183	183	195	190	202	204	209	206	216	213	218	220
Volume of Data	251TB	280TB	298TB	249TB	287TB	360TB	275TB	291TB	315TB	199TB	98.9TB	250TB

This ratio is a product of two separate factors:

- the high proportion of web traffic that is duplicated in a school network
- the proportion of that repeat traffic which **CACHE**BOX is able to recycle

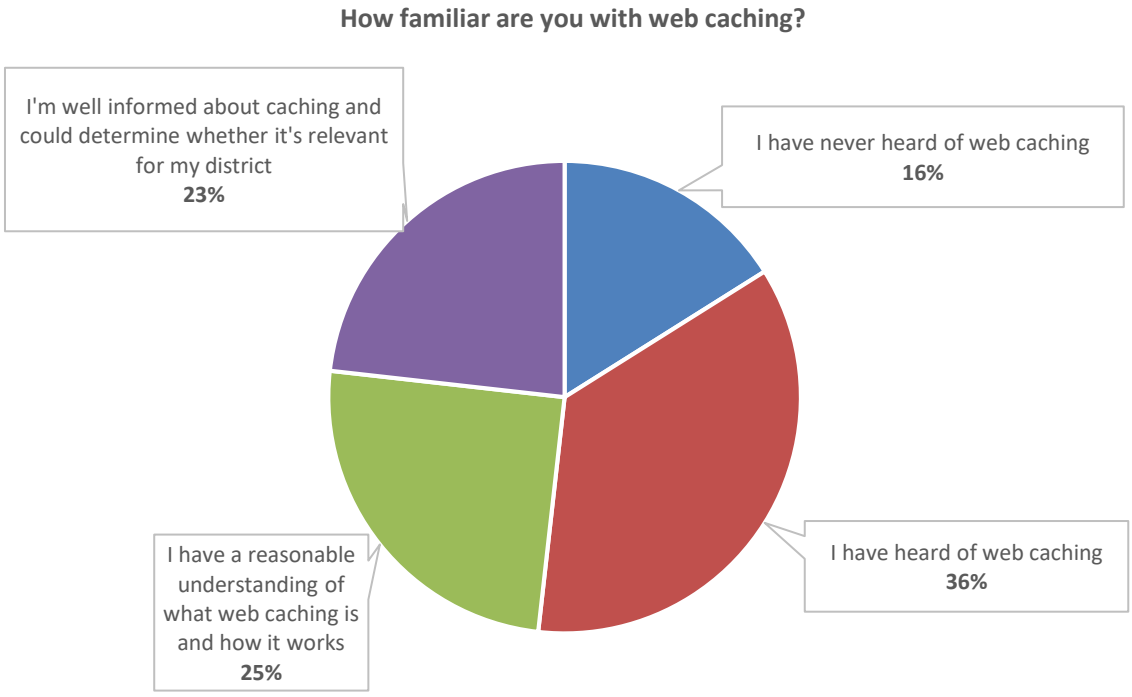
By improving BHR, **CACHE**BOX further reduces the bandwidth capacity requirement for schools, particularly at peak times when much of this repeat content occurs and can be served by cache. A growing proportion of content served by cache also means that more content is being delivered to the classroom at high speed.

We can also see a large spike in August 2018, when 43.9% of all internet requests in these schools were served by **CACHE**BOX. This is due to districts deploying large volumes of student devices during summer, devices which automatically download the latest operating system updates the first time they are switched on. Continued product development has enabled **CACHE**BOX to support more software platforms from more vendors.

This data acts to allay concerns by some technology teams in the sector that caching might be unable to keep up with a changing internet. The data shows that an education-focused cache can continue to perform well. ApplianSys expects to maintain the trend of **CACHE**BOX performance improvement in 2018/9.

2.3 Finding three: Awareness of caching is low, and this is reflected in the number of districts that take it up

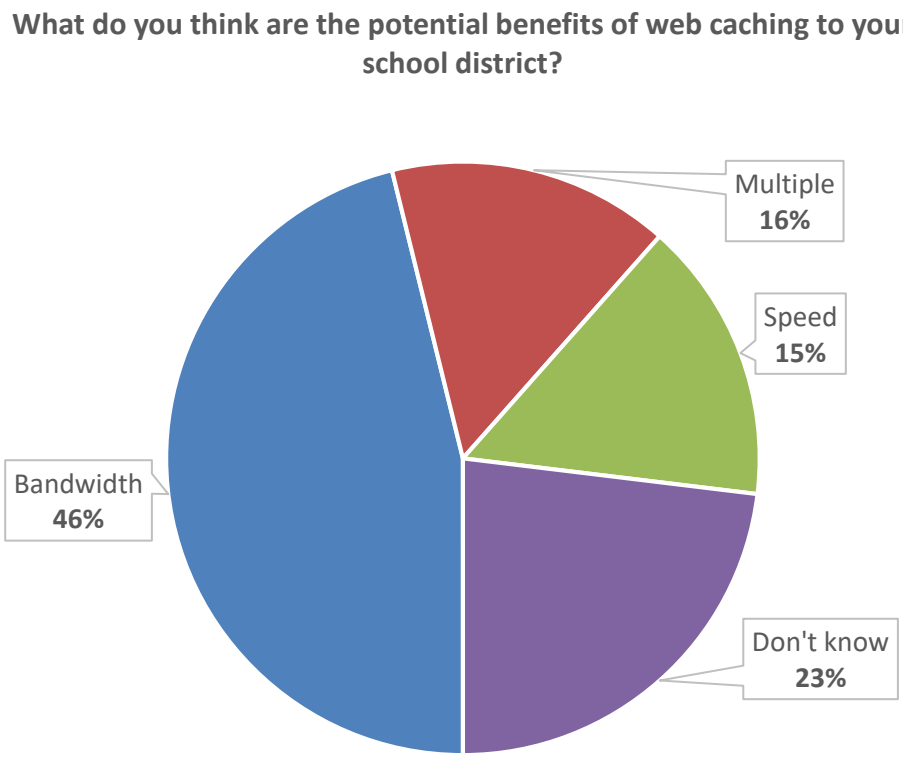
In mid-2018, ApplianSys conducted an unbiased survey of US school districts via online questionnaire and telephone gathering 56 responses. The findings confirm that awareness of the acknowledged benefits of caching technology within the E-rate program is low.



- **Less than half of respondents claimed to have a reasonable understanding of what web caching is,** and less than a quarter felt well informed enough to determine its relevance to their district.

The majority of respondents who claimed to have a reasonable understanding of caching were not aware of benefits beyond saving bandwidth. The graph below shows the responses from just those respondents who answered the previous question either:

- "I'm well informed about caching and could determine whether it's relevant for my district"
- "I have a reasonable understanding of what web caching is and how it works"

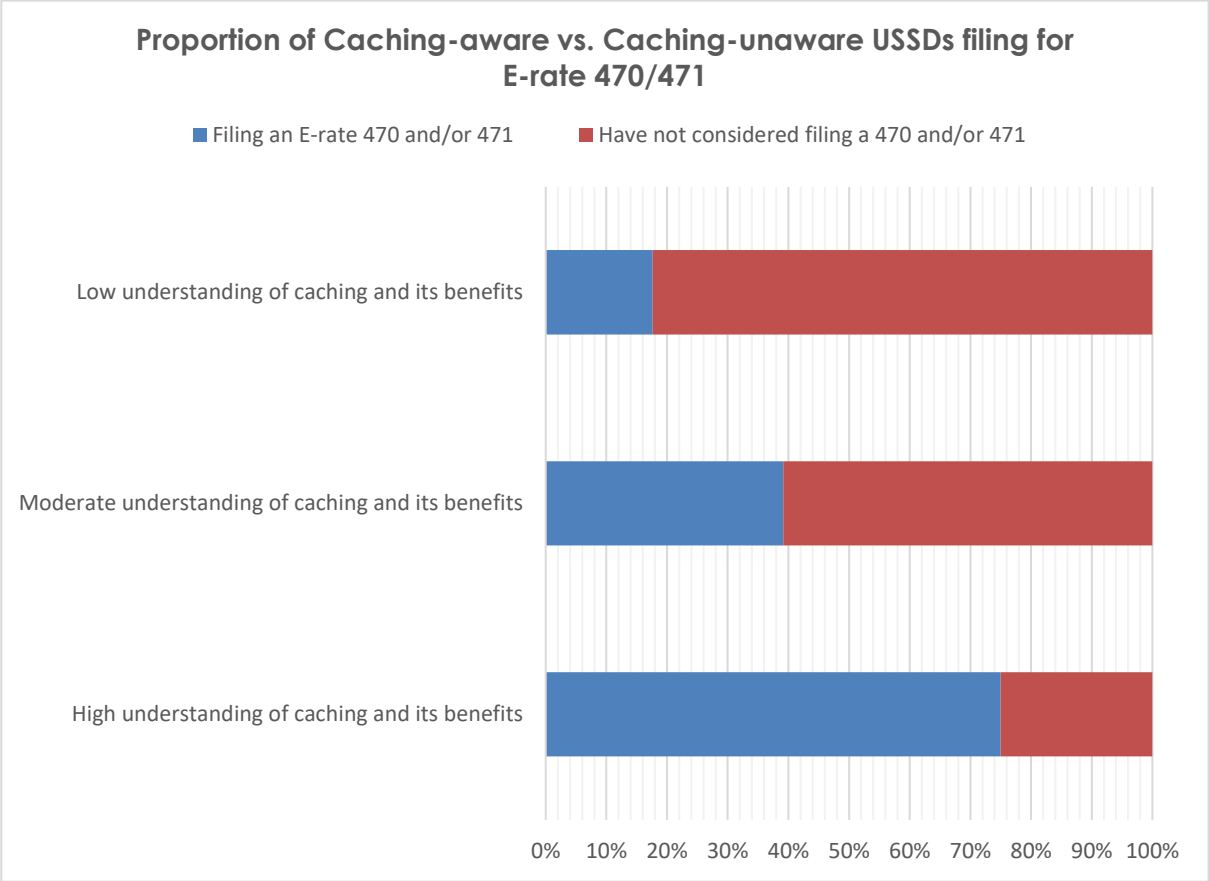


69% of respondents either listed bandwidth savings as the only benefit or responded that they didn't know. So, for many E-rate applicants there's a decision to apply for bandwidth 'or' for caching.

Given that Category 1 budgets are not capped but Category 2 is, it's unsurprising that many would choose to request funding for bandwidth and retain Category 2 budgets for other eligible services.

Those schools that are aware of all the benefits typically apply for e-rate funding to purchase a cache. The following graph shows how, as the level of understanding of web-caching increases, so does the likelihood that a district has filed - or plans to - request funding for caching.

Only 18% of those with a poor understanding of caching plan to file an E-rate 470 and/or 471, compared to 76% of those that are well-informed.



If we extrapolate these findings to the whole school population, then low take-up of caching on E-rate does not equate to a low need for caching, but rather a poor understanding of the benefits it delivers.

2.4 Finding Four: Universal take-up of caching would save US School Districts hundreds of millions of dollars each year

ApplianSys used performance data from school districts with a **CACHE**BOX to extrapolate the potential return on investment nationwide. The following analysis slices and dices a "status quo vs ubiquitous caching" comparison and highlights four key areas of significance:

A: Firstly, we considered the current level of bandwidth provision and how much *less* that would have to have been if schools were all *already* equipped with caching. We based the calculations on the most conservative scenario utilizing 'average bandwidth savings'.

Of course, this can only be a notional figure; even if caches were distributed nationwide today, districts aren't going to reduce their bandwidth capacity and reap those projected savings for the nation. If caches were deployed, they would be in addition to existing bandwidth.

In addition, 'average' savings are not a good guide to the value of caching in schools where 'peak demand' determines the amount of capacity required – and 'peak demand' is largely driven by repeat requests.

B: So, the more informative scenario to consider is that of a universal rollout of caching to *augment* the current bandwidth provision across K12. What impact would that make on:

B-2: the additional peak-serving capacity that schools would no longer need to provision via bandwidth upgrades

B-3: bandwidth affordability

B-4: 'effective' bandwidth provision per pupil

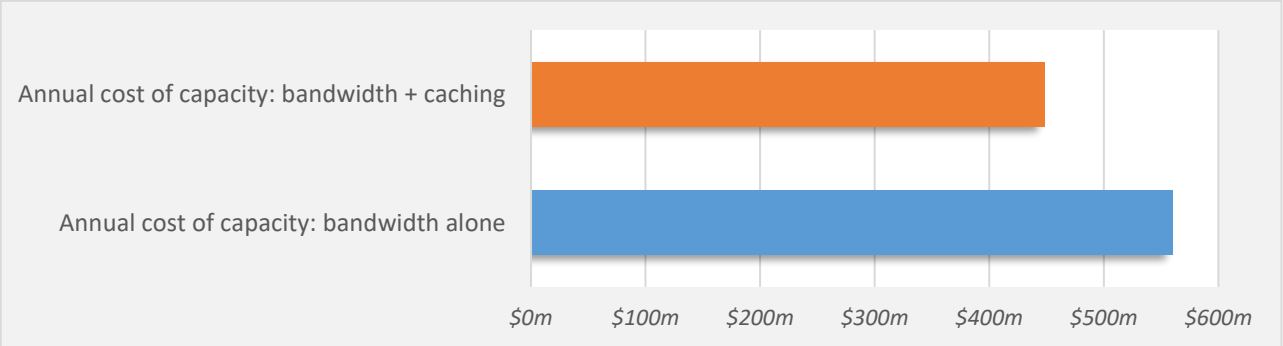
1. Notional Reduction in Current Costs via Average Bandwidth Savings from CACHEBOX: the difference between the cost of the current national bandwidth provision, and the level of bandwidth spend that would have been required to provide the same effective capacity if caching was ubiquitous

Utilizing USAC data for how much each district currently pays for bandwidth and the capacity it purchases, we applied the average bandwidth saving measured at districts with web caching (*35.7% from September 17 to August 18*).

This allows us to estimate how much bandwidth each district would need in order to deliver the same capacity if it had a cache in place.

We can use this new bandwidth requirement to deduce potential cost savings:

- $9.32m per month, that's $112m per annum.
- The annual cost of delivering the equivalent bandwidth to all districts would drop from over $559m to under $448m.



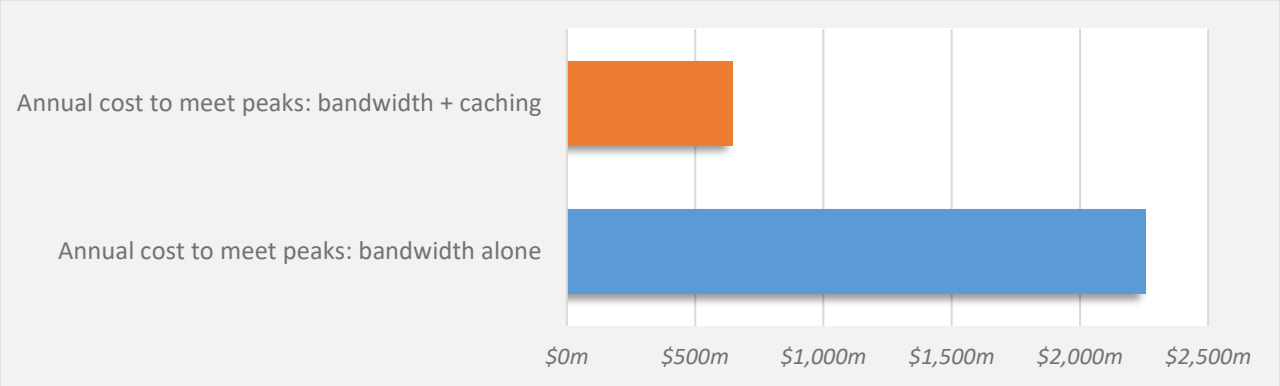
B-2. Value of Caching's Peaks Performance: the additional projected cost of providing with bandwidth alone the peak delivery capability that ubiquitous caching would provide.

Ubiquitous caching applied to the existing bandwidth that districts have provisioned would provide significant additional capacity to handle peaks in demand caused by orchestrated start-of-lesson content requests or device-generated software update spikes.

Peaks in schools' traffic is measured at over 5, often 10 times the average consumption. Because those peaks are largely repeat requests, caching can serve that peak demand without impacting or utilizing the internet connection.

We looked at how much it would cost using internet connections alone to provide for peaks of 4 times the capacity that each district currently has and compared this to the cost of **CACHE**BOX.

- The annual cost to deliver peak demand with bandwidth alone would be over $2.2bn compared with $648m with caching (current bandwidth cost plus $88.1m annualized cost of caching for all schools).
  - That's a massive $1.6bn annual saving.



3. Bandwidth Affordability Improvements from Caching: the reduction in 'effective bandwidth' costs per Mbps that caching delivers

Because of the spikey nature of traffic in schools, caused by repeat requests for content and software updates, bandwidth is an inefficient solution; you need to cover those peaks to avoid congestion, but bandwidth-only management of those peaks results in a whole load of unused capacity outside of those peak times. And the content still arrives at a variety of speeds – many of them suboptimal for modern e-learning needs.

Bandwidth can be far more cost-effectively utilized by serving those repeat requests at LAN speeds from cache and reserving the internet connection for unique requests.

As a result, bandwidth becomes more affordable.

- Aggregated USAC data shows us that districts currently pay significantly more than the FCC affordability targets for all but one of the defined thresholds. With caching creating 'effective capacity', the average **cost per Mbps would go from $5.77 to $1.77** and prices in each range would be much closer to target.

	10Gbps	1Gbps	500Mbps	200Mbps	100Mbps	50Mbps	Avg
What schools pay now	$1.99	$2.96	$12.29	$15.12	$23.27	$98.76	$5.77
FCC targets	$0.75	$3.00	$5.50	$9.00	$12.00	$14.00	($3.23)
With caching effective capacity	$0.25	$0.74	$3.07	$3.78	$5.82	$24.69	$1.77

FCC average target (in parentheses) decduced by calculating the number of districts in each bracket, if all met the 100Kbps per student target, and applying the defined targets

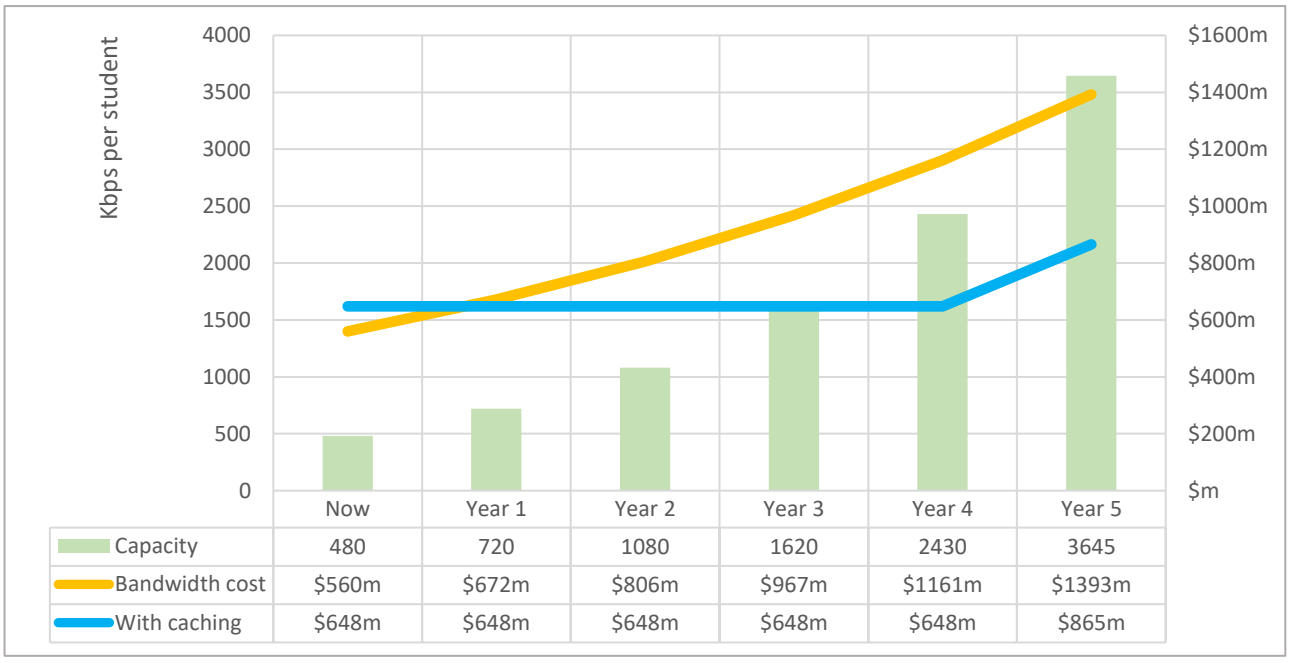
4. 'Effective' Bandwidth Provision per Pupil from Bandwidth + Caching: the cost-effective delivery of national per pupil bandwidth targets by augmenting investments in bandwidth with caches.

Beyond cost savings, a fourth perspective to consider for the impact of a nation-wide rollout is in terms of "the effective bandwidth" provision per pupil; here we differentiate between:

- the actual bandwidth provision from Internet connections without caching, and
- the 'effective' or 'combined' capacity provided by bandwidth serving unique requests while caching serves repeat requests

Caching can help the FCC to meet its own targets for delivering 1Mbps per student in 2018 and meet the expectation that demand will continue to increase 50% per annum.

- The actual capacity per student available, at time of survey, was an average 480kbps.
- If all districts retained their current internet connections and added a cache, the average effective capacity per student would jump to more than 2.44Mbps.
  - At the 50% annual growth rate predicted by EducationSuperHighway, the average capacity per student required will increase from the current 480kbps to 2.43Mbps in 4 years. So, adding caching now would give US districts the capacity they'll need in 4 years' time.
  - At 50% annual growth rate, the need in 5 years' time will reach 3.65Mbps per student. With caching, this effective capacity can be delivered with only a 10% annual increase in internet connection capacity.



	Now	Year 1	Year 2	Year 3	Year 4	Year 5
Capacity	480	720	1080	1620	2430	3645
Bandwidth cost	$560m	$672m	$806m	$967m	$1161m	$1393m
With caching	$648m	$648m	$648m	$648m	$648m	$865m

Bandwidth costs estimated to grow 20% per year whilst capacity grows 50% reflecting the lower cost per Mbps available with larger connections

3. In Conclusion

The data shows that opportunities are being missed – not just in bandwidth cost savings but in securing the best e-Learning experience in which all our students can thrive, regardless of their school's location, size or budget:

- For urban schools, there is the opportunity to haul back the rate of increase of bandwidth and, with it, the attendant costs of the upgrade of other network equipment to deal with the increased capacity
- For one-in-five schools in the US that are bandwidth-constrained, caching can bridge the rural digital divide and deliver the 'effective bandwidth capacity' that schools need while at the same time super-charging the speed of classroom content – with huge affordability improvements

We reason that the need for modern caching technology in schools is compelling and backed by clear evidence. We trust that, at minimum, the FCC will continue to make funding available for caching in future E-Rate cycles.

4. ApplianSys Recommendations to the FCC

In response to requests for comment on the 2017 Eligible Services List, ApplianSys recommended that FCC:

- make caching available for Category One funding
- refine its measurements of affordability to consider capacity delivered by caches
- modify bid evaluation methodology to help districts avoid bandwidth overspend
- take steps to avoid WiFi and caching competing for the same funding
- further research the cost-performance of the use of caching

ApplianSys accepts the decisions not to implement these changes at that time, but urges FCC to reconsider these as it reviews the impact of 2014's E-rate modernization order and determines funding for future years.

ApplianSys additionaly proposes that FCC develops and publishes a more nuanced approach to bandwidth per student targets to avoid encouraging wasteful investment in excessive capacity.

5. Appendix A: Return on Investment Comments

The following tables provide testimonial provided by named School District **CACHE**BOX users about the the impact of caching above and beyond network benefits.

Able to use Advanced Pedagogy

Date	District	Contact	State	Statement
2-19-18	Central Plains	Scott Mitchum	KS	In our area we cannot get more bandwidth even if we wanted to, this is a very real ceiling we are up against in modernizing our learning. So the performance boost from **CACHE**BOX is essential
4-11-18	East Peoria	Paul Stafford	IL	Our apexlearning classes are for challenging high school students, classroom management, learning struggles. Having a reliabily fast connection helps manage these students, and help them reach graduation.
4-13-18	Orient Macksburg	Andrew Rothe	IO	The device has been essential for our eLearning capability. ApexLearning was a mess in the past and now I don't hear anything.
	Bayless School District	Fadil Hamidovic	MO	Prior to **CACHE**BOX, we had no access to youtube or video in classroom. **CACHE**BOX provided unlimited access. At peak times students are drawing 230Mb from a 100Mb pipe, teachers are happy and students have free access to video based independent learning for the first time
4-4-18	Macksville USD	Jaye Dickenson	KS	Teacher were not able to do anything, there was always something that was not working for them, especially during online testing time. Reliability more so than speed was their big problem with lesson planning
3-24-18	Southwest Barrry	Dan Shelton	MO	Video has been a long standing challenge for our teachers. We have been a school wide deployment for media library for all of our teachers to use and issued training materials for them with department leads.
2-2-18	Highland Local Schools	Dana Lehman	OH	Before the **CACHE**BOX, engaging content like pbskids in-class learning games were, as one teacher put it, "unplayable" in the computer lab. Teachers are now using this and others like it regularly.
5-16-18	South Harrison County R2 School District	Dwight Schell, Tech Coordinator	MO	It helps with controlling my bandwidth as well as allowing teachers to use YouTube without opening everything up.
5-3-18	Anahiem Union High School District	Stephen Schickler, Network Technician	CA	Staff benefit too! Aeries Student Information System = 15 x faster

Classroom Acceleration

Date	District	Contact	State	Statement
4-12-18	Alcorn	Dylan Lambert	MS	Found noticeable acceleration as soon as **CACHE**BOX was in place
2-25-18	North Palos 117	Dan Bekas and Erick Grauke	IL	Apeed was a big issue, and now its more stable.
5-1-18	Big Horn	Casey Bowe	WY	Acceleration!
2-19-18	Chase Raymond	Jerry Butler - Carl Hamond	KS	Aside from the problems of being pegged daily. The device has helped with classroom speed which makes lessons more reliable. In shock of how low our need is after the **CACHE**BOX.
3-23-18	Nueces Canyon	Greg Harmon	TX	When we turned our box off for a day, our network slowed down and teachers noticed.

Student Engagement

Date	District	Contact	State	Statement
5-7-18	Snyder ISD	Jeff Mgninnish	TX	We wanted to be able to handle those repeat requests. I think it is working. Media library helpful for keeping kids focused on Youtube.
5-24-18	Carl Junction	Marshall Graham, Tech Director	MO	Teachers able to do stuff without worrying about lag from student to student.
4-26-18	Keokuk	Brent Haegar	IO	None - but getting tremendous speed increases
4-13-18	Emmetsburg	Bryan Ruff, IT Director	IO	Students upload and share content cia the district website - before **CACHE**BOX was put in, it was far too slow to be usable. Now, students and teachers can use it much more easily
3-24-18	Nueces Canyon	Greg Harmon	TX	Teachers Reported Restless students do to user wait.n Which made teachers less likely to do tech lessons

Fewer teacher complaints

Date	District	Contact	State	Statement
6-27-18	Raymore Peculiar (middle school only)	Jason Smither	MO	Daily stoppage has completely stopped that was happening before the cachebox. Performance on edu content noticabily better at cachebox site compared to the rest of the district. Noticable reduction in performance issues at the school buidlig with the cachebox. Fewer complaints about slowness and error. Only one update since past four years vs 3 updates in last four years at the rest of the district.
6-1-18	Airport Community	Aaron Gurul, Director of Technology	MI	Extreme acceleration of cached content, average request is 67x faster. complaints stopped. Things are faster. Less busy work for me and more real work.
5-21-18	Barnesvile 146	Casey Elhert	MN	none reported but teachers are able to use google better is the one area he commented on.
4-4-18	McGregor ISD	Jack Brula	MN	Teachers are able to use video in the classroom and I don't get any complaints. No more teacher tickets and emails saying it's not working any more.
6-21-18	USD 440	Lincon Quintid	KS	The update server is better than microsoft as it covvers more of them (apple, google, windows, microsoft) and it requires less maitenance. Works better as a focused device, dedicated with dedicated processing.
5-31-18	Southeast Webster	Dan Flukenginer	IO	**CACHE**BOX was added to the network in April just before state testing. before then there had been regular congestion and chllenges. But this past month with the cachebox during testing season, he did not hear a single incidence of network problems. Ease of testing implementation is critical for student/district success
4-11-18	East Peoria	Paul Stafford	IL	After we updated to the **CACHE**BOX but before we had updated our bandwidth, teachers were reporting that things are working better.
5-24-18	Jefferson High School	Alan Smith	MT	We precache a lot of our specific content for our onine learning classes and our credit recovery and using the pre-cache feature the teachers are able to use the classwork again before things were unusable.
2-19-18	Cascade Falls	David Dobbins	MT	I continue to tell people about my 20% workload decrease due to the addition of the **CACHE**BOX. That's a real number, and opens up time for fishing on the Missouri River". I'd recommend ApplianSys because **CACHE**BOX was the perfect solution for our small rural school. We had low bandwidth and growing number of devices all requesting similar data from the internet. A caching device was the obvious choice.
3-29-18	Franklin Area School District	Scott Armburger, Tech Director	PA	The box has really made a difference in keeping us where we need to be. Especially with teachers, we flat out don't hear from them anymore on things not working.

9-4-18	Oak Grove School District R6	Ryan Word Director of Tech	MO	I stopped getting complaints from teachers! In fact, I'm not getting any complaints from teachers anymore!
3-23-18	Nueces Canyon	Greg Harmon	TX	When we turned our box off for a day, our network slowed down and teachers noticed.

Lessons on track

Date	District	Contact	State	Statement
5-7-18	Prarie Valley	Vicki Johnson	IO	We really struggled with buffering and stites not working half way through a lesson. Windows dying etc. Nothing since the cachebox was put in place
4-26-18	Arkadelphia	Joey Andrews	AK	Not getting backed up daily
2-2-18	Highland Local Schools	Dana Lehman	OH	Before installing the **CACHE**BOX, Chromebook updates would result in 3 days of nearly unusable internet experience for classroom teachers. Since then, I have been able to run updates with almost no interruptions.

Trouble-free online testing

Date	District	Contact	State	Statement
6-12-18	Blanco ISD	James Caudwell, Network Administrator	TX	This is the first year that they have gone through online testing season without any stoppages or challenges. The same month they first had their cachebox deployed.
5-31-18	Southeast Webster	Dan Flukenginer	IO	**CACHE**BOX was added to the network in April just before state testing. before then there had been regular congestion and chllenges. But this past month with the cachebox during testing season, he did not hear a single incidence of network problems. Ease of testing implementation is critical for student/district success
4-4-18	Quakertown Christian	Kenneth Herr	PA	We had to do something because we can only afford cable in our area. Fiber is too expensive. So in order to keep things going faster for teachers like online testing, the **CACHE**BOX is perfect
4-4-18	Macksville USD	Jaye Dickenson	KS	Teacher were not able to do anything, there was always something that was not working for them, especially during online testing time. Reliability more so than speed was their big problem with lesson planning

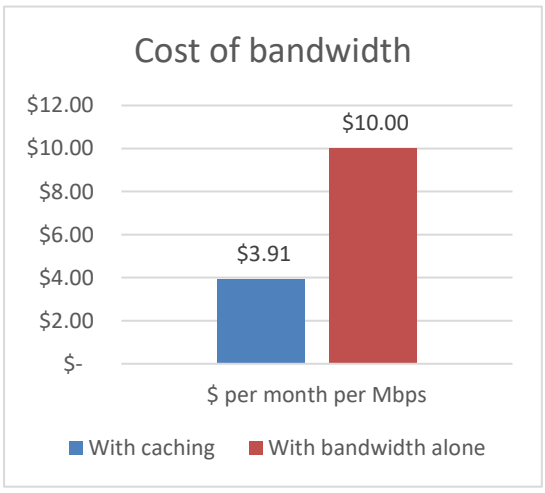
6. Appendix B: Additional school district caching profiles

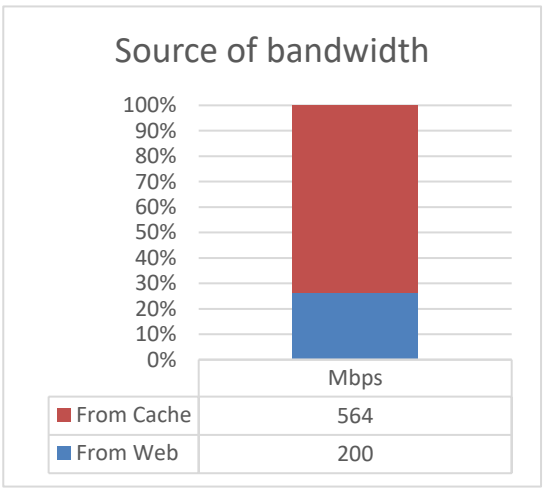
Newcomerstown district in Ohio receives 200Mbps from its Regional Education Service Agency (RESA) at a cost of $2000 per month. Despite reaching it's 2017 capacity per student target, Newcomerstown often found its network congested. When students were directed to specific content at the start of lessons, access slowed - page-load times spiralled - and lessons were negatively impacted.

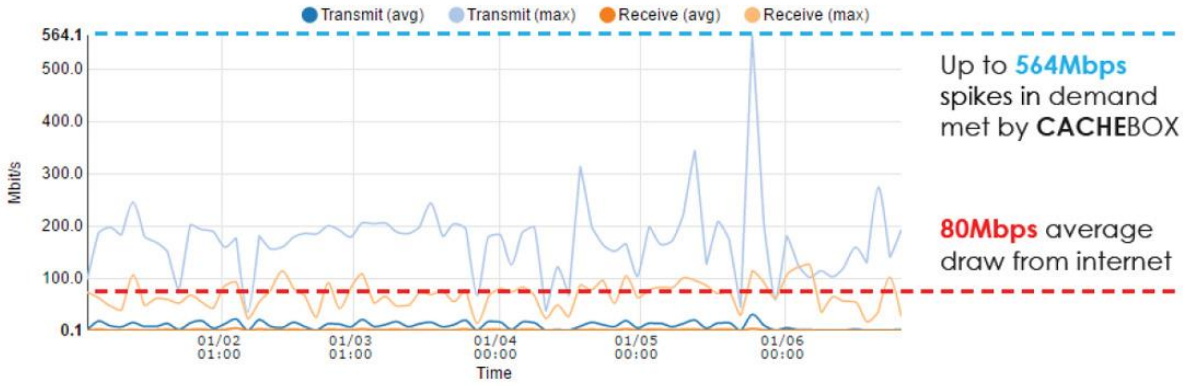
CACHEBOX has revealed that peak demand is as high as 564Mbps, almost 3 times its existing capacity and this would typically have prompted the RESA to upgrade capacity. With **CACHE**BOX in place, this has not been required.

*"Our Service Provider is the Ohio Mid-Eastern Regional Education Service Agency. They have to upgrade their bandwidth every year due to schools overconsuming compared to their plan. When we put the **CACHE**BOX in, our bandwidth consumption finally dropped such that we went below our 200Mbps, which the RESA immediately noticed."*

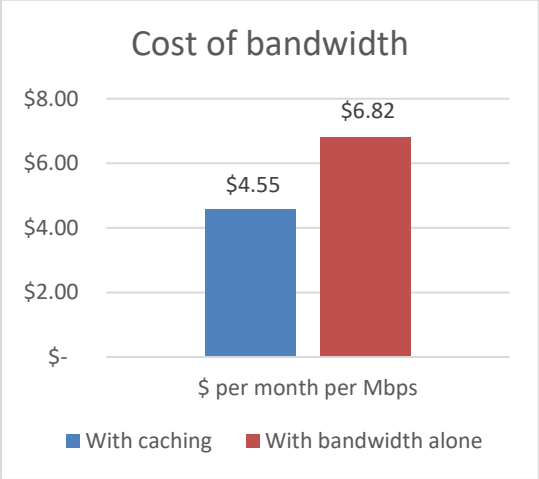
Shawn Dakin, Network Administrator, Newcomerstown

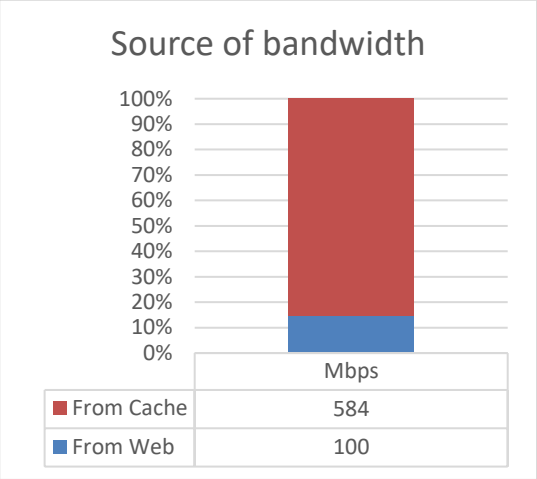






Cascade School District 3 is a 300 student district in rural Montana that pays $900 per month for an 100Mbps internet connection. Since the district deployed caching in 2015 it has benefited from up to 580 Mbps of capacity at one fifth the price per Mbps.

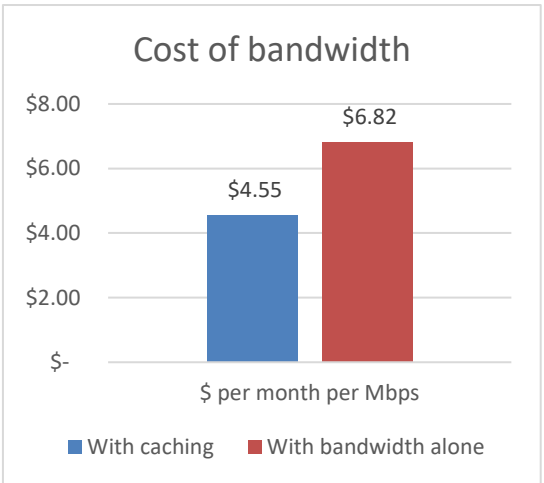


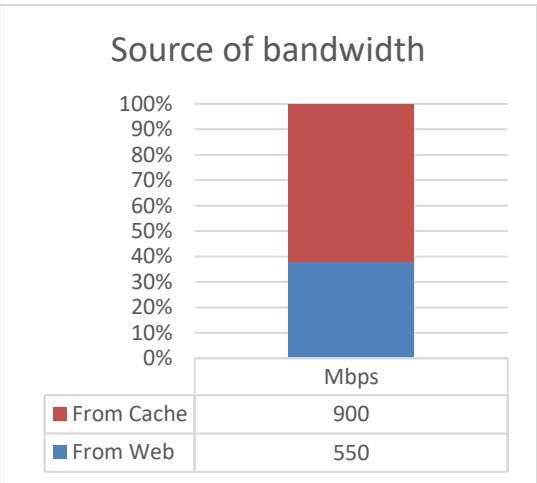


"We had low bandwidth and a growing number of devices all requesting similar data. **CACHE**BOX was the perfect solution for our small rural school."

David Dobbins, Network Manager, Cascade School District 3

Browning Schools in rural Montana currently serves its 550 Mbps connection across its 10 sites to 2000 students at a cost of $3750. Since they deployed CACHEBOX in their network their virtual capacity has almost doubled reducing their monthly costs per Mbps.

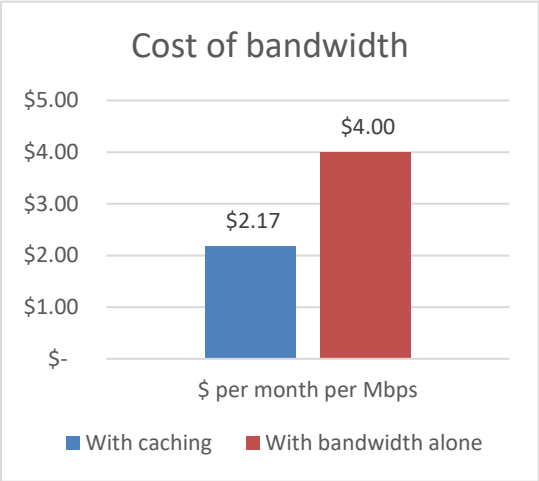


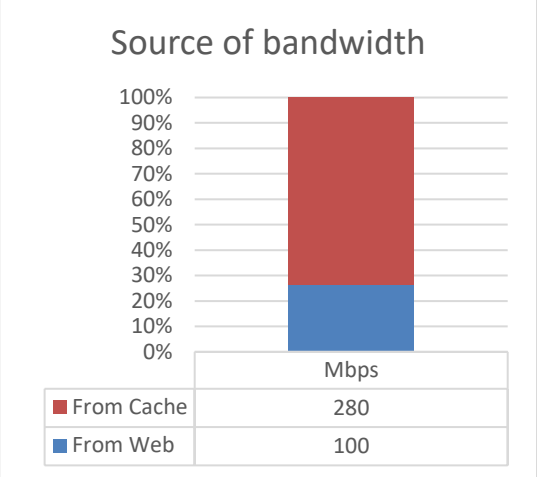


*"Between managing my software updates and increasing the speed the **CACHE**BOX is working as it should and it is easy to manage. We will be able to stay at our current bandwidth until end of our contract in 2019 because of the **CACHE**BOX."*

Everett Holm, Network Manager, Browning Schools

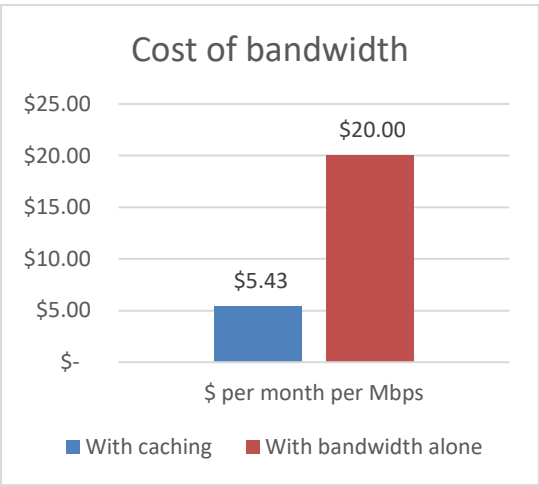
Technology Center of Du Page in Addison, Illinois, is a technical school with a 100Mbps connection and approximately 1000 network users. **CACHE**BOX is providing over 2X their original capacity at ½ the price per Mbps.

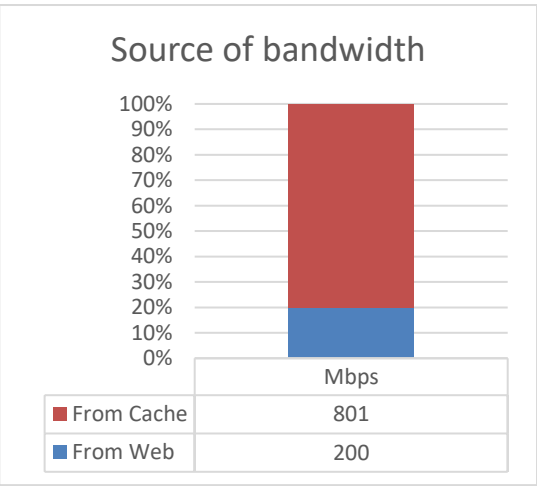




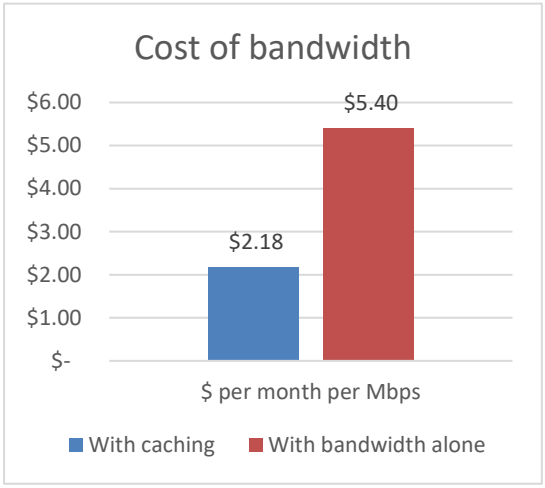
*"I haven't had to upgrade my bandwidth in 3 years! The **CACHE**BOX is a part of that."*
Marek Adamczyk, Network Administrator, **Technology Center Du Page**

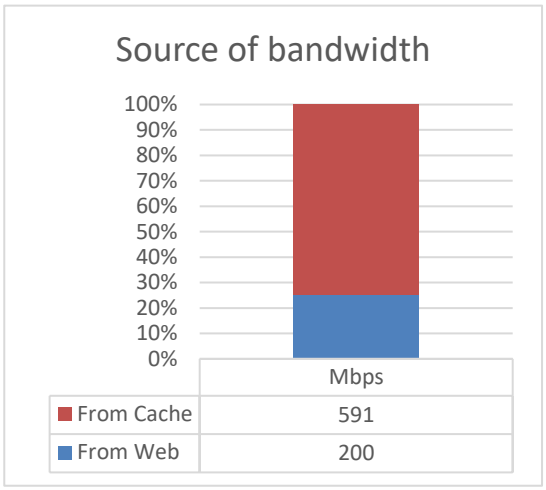
Big Horn is a small 300 student district in Wyoming that pays $275 per month for an 200Mbps internet connection. Since the district deployed caching in 2017 their virtual capacity has quadrupled allowing them to benefit from up to 800 Mbps of capacity at one forth the price per Mbps.





In rural Montana, bandwidth often comes at a high price. **Ronan School District** pays over $1000 for a 200Mbps connection to cater for its 1400 students at 2 campuses. But as web-based learning and device numbers have grown, so has traffic from the classroom. With **CACHE**BOX, Ronan has accelerated classroom content by an average 7x faster than from the internet, increased their capacity to 591 Mbps and slashed their Mbps monthly cost to less than half.





"The device is incredibly easy to use. I takes very little maintenance on my part, which is extremely important to me as I have enough items already that I need to keep an eye on."
Dustin Rowe, Information Technology Director, Ronan School District

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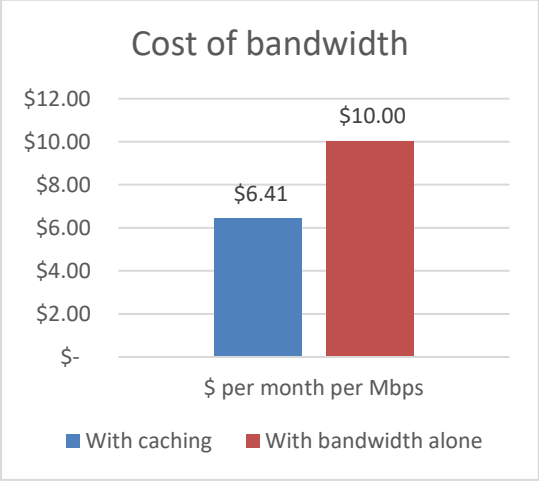
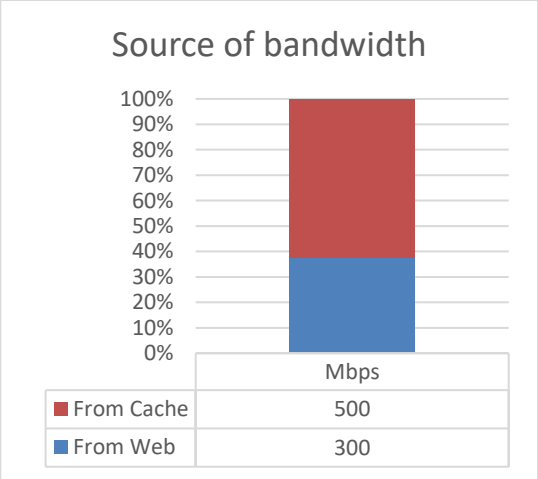
In a rural setting but with 1800 students, **Highland Local Schools** would struggle to meet the 100Kbps per student target without extremely high cost. But with caching, education content from providers like Starfall, ABCya!, storylineonline, roomrecess, and mathplayground is delivered between 20 and 40 times faster from **CACHE**BOX than it's 100Mbps link.

Domain	From Web (Mbps)	From Cache (Mbps)	Speed increase
starfall.com	1.3	61.1	46.5
microsoft.com	12.1	514.1	42.6
abcya.com	1.3	49.2	37.6
turner.com	0.3	11.3	37.0
storylineonline.net	0.3	10.6	32.7
roomrecess.com	0.4	10.1	28.3
www.thelearningodyssey.com	1.1	27.4	23.8
mathplayground.com	2.8	59.8	21.1
annefrank.org	1.8	36.5	20.5
netsmartz.org	13.8	273.9	19.8
abcya.com	2.5	45.4	17.9
apple.com	6.1	104.6	17.2
ballparksofbaseball.com	1.8	28.3	16.0
edgesuite.net	1.6	23.5	14.7
kidsciencechallenge.com	5.9	85.9	14.5
naturalhistory.si.edu	3.6	50.5	13.9
windowsupdate.com	1.2	15.8	13.5

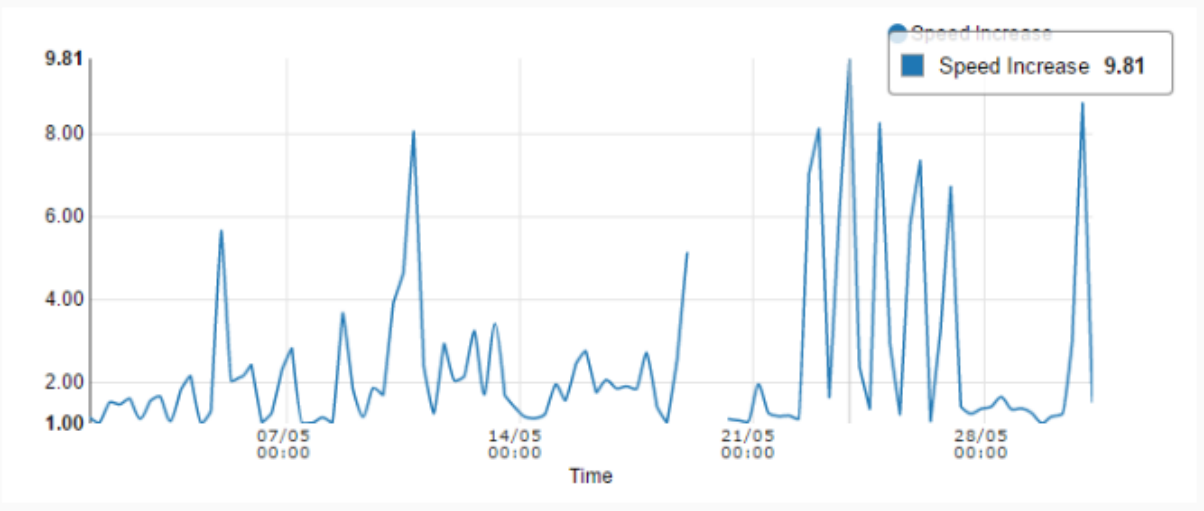
As **Hannibal SD** expanded e-learning across its 8 schools, it quickly found its 300Mbps network congested and unable to serve it's 3700 users. With caching Hannibal SD was able to store popular content locally and stream it direct to end-users from within the LAN, freeing up enough space for bandwidth-hungry content such as YouTube and dramatically accelerating learning content up to- 15, 22 and even 97 times faster!

Domain	% served from cache	From Web (Mbps)	From Cache (Mbps)	Speed increase
*.rosettastone.com	92.0%	0.12	120.5	97x
*.bbc.co.uk	90.7%	0.13	43.4	34x
*.starfall.com	84.5%	0.14	44.4	32x
*.adaptedmind.com	97.2%	0.10	21.6	22x
*.hannibalclinic.com	94.2%	0.23	42.7	18x
*.k12.mo.us	88.1%	0.05	7.5	16x
*.usc.edu	86.2%	0.08	12.7	15x
*.commoncoresheets.com	92.8%	0.10	15.8	15x
*.discoveryeducation.com	66.3%	0.45	40.6	9x

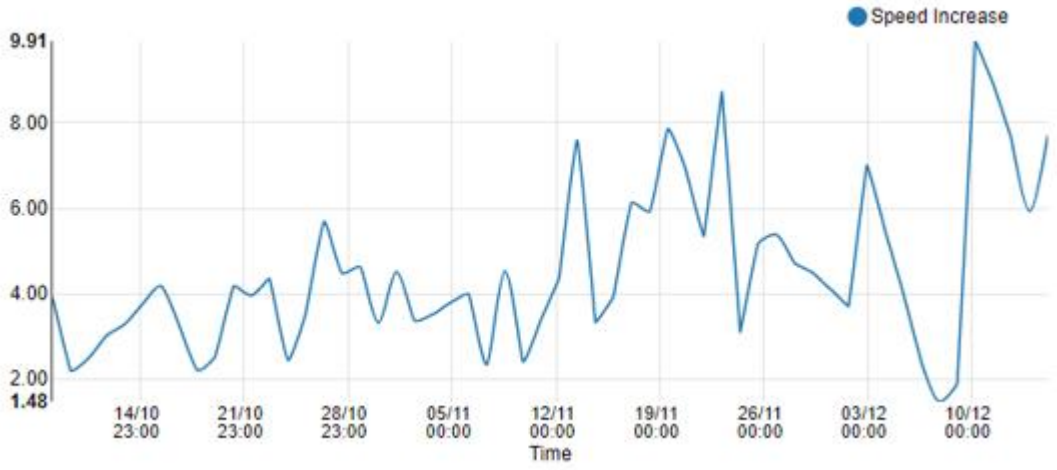




At **North Ottawa County USD 239** web requests are typically twice as fast and as much as 14x faster from **CACHE**BOX than from the internet. This rural school has maximised the use of its 100 Mbps connection and is now benefitting from great acceleration in the classroom and instant internet access for its 641 students.



Airport Community School District in Michigan had a healthy 1Gbps Internet connection. Yet the connection speed to their six buildings was proving too slow for their 700+ concurrent users, which was causing YouTube and bandwidth-heavy video content to buffer. Following their **CACHE**BOX deployment in 2017, the district has seen consistent savings and students are able to enjoy a much faster access to e-Learning content. At times, they are accessing content 9 times faster than via the Internet.

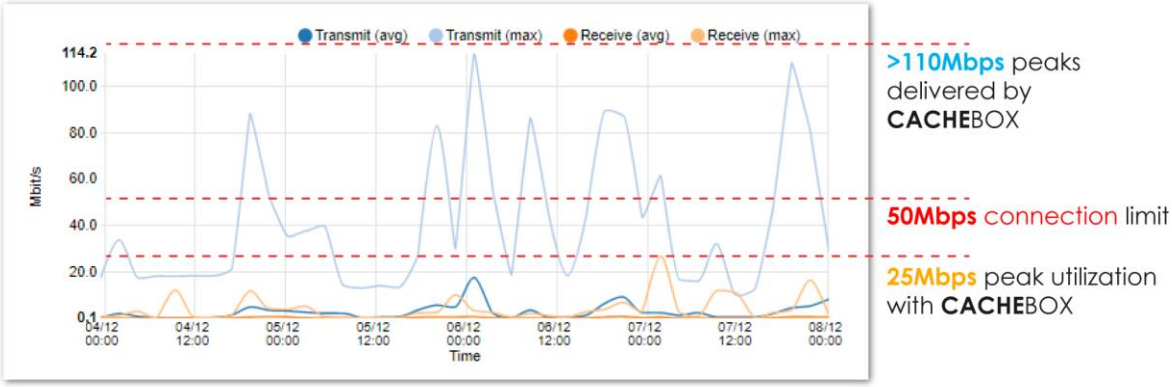


Claremont Unified, a large district in California with 7,000 students, relies on its 1Gbps internet pipeline to serve its growing BYOD scheme, as well as 2,300 district-owned devices. However, expanding BYOD across its 10 sites and adding more iPads has caused a dramatic slowdown in web access. With **CACHE**BOX, Claremont has defeated the slow, problematic Apple updates that were hogging bandwidth and made its network capacity available for more users and more educational content, enabling a more responsive learning experience.

Domain	Total Traffic (GB)	Traffic from cache (GB)	BHR%
Overall	2463	1616	66%
apple.com	1619	1136	70%
cdn-apple.com	399	293	74%
windowsupdate.com	136	108	79%
microsoft.com	59	52	88%
coolmath-games.com	13	9	69%
adobe.com	9	6	67%
mozilla.net	5	4	86%

Top cache domains, July 2018

To maintain low tuition fees, **Calexico Mission School** in California operates on much lower-than-average budgets. This school opted for a small leap in bandwidth from 15Mbps to 50 Mbps combined to **CACHE**BOX to make up for the additional capacity needed at peak times. Thanks to caching Calexico Mission has been able to handle peak web traffic well above 100Mbps, with their content being served from the local cache 4 times faster than that from the internet. By doubling effective capacity without breaking the bank, the school has been able to add more student devices and can realistically consider introducing a BYOD scheme.



7. Appendix C - Caching cost saving data

The following tables show the results of the data extrapolation activity described above. Colour coding shows related columns between current costs and ApplianSys' extrapolation data.

This data will also be provided separately in an Excel Spreadsheet.

		Current Internet Access Costs					With Caching							
State	Total Bandwidth (Mbps)	Bandwidth per Student (Mbps)	Average Monthly cost	Avg. Monthly cost per Mbps	Total Monthly Cost	Total Annual Cost	Internet access needed with a cache (Mbps)	Internet Access per student needed with cache (Mbps)	Statewide Monthly cost of caching	Monthly cost of bandwidth with caching	Monthly cost reduction	Annual cost of bandwidth with caching	Annual cost reduction ($)	Monthly cost per Mbps with caching
Alabama	184,590	0.256	$7,156	$6.1	$0.96m	$11.51m	118,661	0.16	$74,655	$0.69m	$268k	$8.29m	$3.21m	$2.75
Alaska	16,069	0.130	$119,303	$1,070.6	$6.32m	$75.88m	10,330	0.08	$29,309	$4.09m	$2,229k	$49.13m	$26.75m	$2.76
Arizona	353,617	0.312	$4,090	$13.2	$1.15m	$13.79m	227,317	0.20	$305,809	$1.04m	$105k	$12.54m	$1.26m	$2.78
California	3,178,849	0.551	$5,393	$9.2	$3.60m	$43.23m	2,043,470	0.35	$515,949	$2.83m	$771k	$33.98m	$9.25m	$4.53
Arkansas	606,695	1.322	$5,754	$2.4	$1.17m	$14.02m	390,003	0.85	$128,849	$0.88m	$288k	$10.56m	$3.46m	$1.23
Colorado	216,640	0.278	$2,886	$5.2	$0.44m	$5.26m	139,263	0.18	$98,434	$0.38m	$58k	$4.57m	$0.70m	$4.15
Connecticut	323,409	0.653	$1,475	$1.0	$0.22m	$2.62m	207,898	0.42	$89,586	$0.23m	-$12k	$2.76m	-$0.14m	$0.76
District of Columbia	11,000	0.236	$17,800	$1.6	$0.02m	$0.21m	7,071	0.15	$553	$0.01m	$6k	$0.14m	$0.07m	$0.63
Delaware	85,200	0.746	$8,017	$2.1	$0.12m	$1.44m	54,769	0.48	$9,401	$0.09m	$34k	$1.04m	$0.40m	$0.96
Florida	415,711	0.166	$12,619	$3.0	$0.78m	$9.39m	267,233	0.11	$37,604	$0.54m	$242k	$6.49m	$2.90m	$1.33
Georgia	435,655	0.259	$5,009	$3.9	$0.79m	$9.50m	280,054	0.17	$99,540	$0.61m	$183k	$7.30m	$2.20m	$2.06
Hawaii	97,300	0.581	$355,597	$3.7	$0.36m	$4.27m	62,548	0.37	$553	$0.23m	$126k	$2.75m	$1.52m	$1.31
Iowa	202,667	0.408	$2,339	$6.7	$0.67m	$8.06m	130,281	0.26	$183,043	$0.61m	$57k	$7.37m	$0.68m	$4.64
Idaho	113,778	0.416	$2,590	$7.1	$0.26m	$3.14m	73,140	0.27	$63,042	$0.23m	$30k	$2.77m	$0.36m	$4.45
Illinois	739,982	0.388	$2,712	$6.7	$1.97m	$23.69m	475,685	0.25	$470,050	$1.74m	$235k	$20.87m	$2.82m	$4.80
Indiana	476,862	0.483	$4,170	$4.4	$1.16m	$13.91m	306,542	0.31	$159,817	$0.91m	$254k	$10.86m	$3.05m	$2.24
Kansas	274,063	0.568	$2,538	$6.0	$0.65m	$7.83m	176,177	0.37	$158,158	$0.58m	$75k	$6.93m	$0.90m	$4.26
Kentucky	144,620	0.220	$5,116	$9.7	$0.85m	$10.25m	92,967	0.14	$95,669	$0.64m	$209k	$7.74m	$2.51m	$4.92
Louisiana	308,810	0.482	$8,665	$3.3	$0.55m	$6.55m	198,513	0.31	$38,157	$0.39m	$157k	$4.67m	$1.88m	$1.37
Massachussets	282,630	0.322	$3,016	$4.7	$0.78m	$9.41m	181,684	0.21	$162,582	$0.67m	$118k	$8.00m	$1.41m	$3.69
Maryland	189,650	0.214	$13,338	$3.3	$0.28m	$3.36m	121,913	0.14	$13,272	$0.19m	$87k	$2.32m	$1.04m	$1.99
Maine	197,625	1.138	$1,105	$2.5	$0.17m	$2.03m	127,040	0.73	$101,199	$0.21m	-$41k	$2.52m	-$0.49m	$2.51
Michigan	994,769	0.745	$1,613	$3.9	$0.71m	$8.57m	639,471	0.48	$298,620	$0.76m	-$43k	$9.09m	-$0.52m	$2.85
Minnesota	469,183	0.593	$2,965	$3.7	$0.89m	$10.71m	301,606	0.38	$181,937	$0.76m	$137k	$9.07m	$1.64m	$2.15
Missouri	479,569	0.554	$2,236	$9.1	$1.02m	$12.21m	308,283	0.36	$285,901	$0.94m	$77k	$11.28m	$0.93m	$7.18
Mississippi	133,012	0.269	$4,270	$5.1	$0.51m	$6.10m	85,505	0.17	$79,632	$0.41m	$102k	$4.88m	$1.22m	$2.48
Montana	74,162	0.509	$1,012	$8.1	$0.23m	$2.77m	47,674	0.33	$165,900	$0.31m	-$84k	$3.77m	-$1.00m	$15.78
North Carolina	399,600	0.272	$12,955	$4.3	$1.43m	$17.10m	256,876	0.17	$63,595	$0.98m	$445k	$11.76m	$5.34m	$1.81
North Dakota	57,170	0.500	$1,474	$11.5	$0.21m	$2.56m	36,751	0.32	$96,222	$0.23m	-$20k	$2.80m	-$0.24m	$8.91
Nebraska	162,290	0.529	$1,518	$6.8	$0.33m	$3.99m	104,325	0.34	$135,485	$0.35m	-$17k	$4.19m	-$0.20m	$4.67

		Current Internet Access Costs					With Caching							
State	Total Bandwidth (Mbps)	Bandwidth per Student (Mbps)	Average Monthly cost	Avg. Monthly cost per Mbps	Total Monthly Cost	Total Annual Cost	Internet access needed with a cache (Mbps)	Internet Access per student needed with cache (Mbps)	Statewide Monthly cost of caching	Monthly cost of bandwidth with caching	Monthly cost reduction	Annual cost of bandwidth with caching	Annual cost reduction ($)	Monthly cost per Mbps with caching
New Hampshire	91,037	0.516	$1,695	$6.2	$0.20m	$2.40m	58,521	0.33	$90,139	$0.22m	-$19k	$2.62m	-$0.22m	$5.66
New Jersey	614,190	0.479	$3,053	$5.7	$1.44m	$17.29m	394,822	0.31	$301,938	$1.23m	$213k	$14.74m	$2.55m	$4.42
New Mexico	114,064	0.365	$4,695	$10.0	$0.38m	$4.62m	73,324	0.23	$49,217	$0.30m	$88k	$3.56m	$1.06m	$5.98
Nevada	130,853	0.305	$6,484	$1.8	$0.06m	$0.78m	84,116	0.20	$9,401	$0.05m	$14k	$0.61m	$0.17m	$0.97
New York	927,650	0.359	$2,212	$3.0	$1.40m	$16.80m	596,324	0.23	$378,252	$1.28m	$122k	$15.34m	$1.46m	$1.96
Ohio	928,911	0.578	$2,872	$5.3	$1.68m	$20.16m	597,135	0.37	$337,330	$1.42m	$263k	$17.01m	$3.15m	$3.06
Oklahoma	469,454	0.720	$2,799	$7.9	$1.29m	$15.45m	301,781	0.46	$282,583	$1.11m	$177k	$13.32m	$2.13m	$4.81
Oregon	325,010	0.595	$2,330	$8.9	$0.31m	$3.77m	208,927	0.38	$98,987	$0.30m	$13k	$3.61m	$0.16m	$5.92
Pennsylvania	1,274,775	0.799	$2,385	$2.3	$1.12m	$13.42m	819,468	0.51	$275,947	$1.00m	$124k	$11.94m	$1.48m	$1.45
Rhode Island	35,255	0.267	$5,777	$8.9	$0.18m	$2.22m	22,663	0.17	$19,908	$0.14m	$46k	$1.66m	$0.55m	$3.97
South Carolina	164,872	0.227	$2,975	$2.6	$0.24m	$2.93m	105,985	0.15	$46,452	$0.20m	$41k	$2.44m	$0.49m	$1.69
South Dakota	102,862	0.772	$1,861	$6.5	$0.25m	$3.04m	66,123	0.50	$82,950	$0.25m	$7k	$2.95m	$0.09m	$4.32
Tennessee	323,200	0.341	$12,919	$8.8	$1.72m	$20.62m	207,764	0.22	$78,526	$1.18m	$535k	$14.20m	$6.42m	$3.62
Texas	2,031,569	0.405	$4,241	$13.1	$4.25m	$51.04m	1,305,960	0.26	$565,719	$3.30m	$953k	$39.60m	$11.44m	$6.99
Utah	230,000	0.404	$14,191	$3.1	$0.51m	$6.13m	147,852	0.26	$22,673	$0.35m	$160k	$4.21m	$1.92m	$1.42
Virginia	373,928	0.295	$6,797	$5.0	$0.82m	$9.79m	240,373	0.19	$72,996	$0.60m	$218k	$7.17m	$2.62m	$2.43
Vermont	79,666	0.993	$3,020	$5.8	$0.16m	$1.92m	51,212	0.64	$30,968	$0.13m	$26k	$1.61m	$0.31m	$3.39
Washington	411,676	0.382	$2,386	$6.8	$0.66m	$7.87m	264,639	0.25	$164,241	$0.59m	$70k	$7.03m	$0.84m	$4.20
Wisconsin	544,292	0.664	$2,275	$3.6	$0.77m	$9.28m	349,889	0.43	$233,366	$0.73m	$43k	$8.77m	$0.51m	$2.31
West Virginia	98,705	0.356	$7,595	$4.5	$0.38m	$4.56m	63,451	0.23	$30,415	$0.27m	$105k	$3.29m	$1.26m	$2.02
Wyoming	58,910	0.638	$4,375	$10.5	$0.19m	$2.26m	37,869	0.41	$26,544	$0.15m	$41k	$1.77m	$0.49m	$5.61
TOTAL	20,956,050	0.48	$14,033	$26.65	$46.6m	$559.7m	13,471,247	0.31	$7,341,075	$37.32m	$9.32m	$447.89m	$111.81m	$3.57

Meeting Peaks data

		Current Internet Access Costs					Meeting peaks					
State	Total Bandwidth (Mbps)	Bandwidth per Student (Mbps)	Average Monthly cost	Avg. Monthly cost per Mbps	Total Monthly Cost	Total Annual Cost	Estimated peak demand (4x bandwidth) - Mbps	Peak demand per student (Mbps)	Monthly cost to meet peaks with internet alone.	Annual cost to meet peaks with bandwidth	Annual cost to meet peaks with caching	Caching saving over bandwidth
Alabama	184,590	0.256	$7,156	$6.1	$0.96m	$11.51m	738,360	1.03	$3.84m	$46.03m	$8.29m	$37.74m
Alaska	16,069	0.130	$119,303	$1,070.6	$6.32m	$75.88m	64,277	0.52	$25.29m	$303.51m	$49.13m	$254.38m
Arizona	353,617	0.312	$4,090	$13.2	$1.15m	$13.79m	1,414,468	1.25	$4.60m	$55.16m	$12.54m	$42.63m
California	3,178,849	0.551	$5,393	$9.2	$3.60m	$43.23m	12,715,396	2.20	$14.41m	$172.91m	$33.98m	$138.93m
Arkansas	606,695	1.322	$5,754	$2.4	$1.17m	$14.02m	2,426,778	5.29	$4.67m	$56.06m	$10.56m	$45.51m
Colorado	216,640	0.278	$2,886	$5.2	$0.44m	$5.26m	866,560	1.11	$1.75m	$21.06m	$4.57m	$16.49m
Connecticut	323,409	0.653	$1,475	$1.0	$0.22m	$2.62m	1,293,634	2.61	$0.87m	$10.48m	$2.76m	$7.72m
District of Columbia	11,000	0.236	$17,800	$1.6	$0.02m	$0.21m	44,000	0.94	$0.07m	$0.85m	$0.14m	$0.71m
Delaware	85,200	0.746	$8,017	$2.1	$0.12m	$1.44m	340,800	2.98	$0.48m	$5.77m	$1.04m	$4.73m
Florida	415,711	0.166	$12,619	$3.0	$0.78m	$9.39m	1,662,844	0.66	$3.13m	$37.55m	$6.49m	$31.07m
Georgia	435,655	0.259	$5,009	$3.9	$0.79m	$9.50m	1,742,620	1.04	$3.17m	$37.99m	$7.30m	$30.69m
Hawaii	97,300	0.581	$355,597	$3.7	$0.36m	$4.27m	389,200	2.32	$1.42m	$17.07m	$2.75m	$14.32m
Iowa	202,667	0.408	$2,339	$6.7	$0.67m	$8.06m	810,666	1.63	$2.69m	$32.22m	$7.37m	$24.85m
Idaho	113,778	0.416	$2,590	$7.1	$0.26m	$3.14m	455,112	1.66	$1.05m	$12.56m	$2.77m	$9.78m
Illinois	739,982	0.388	$2,712	$6.7	$1.97m	$23.69m	2,959,928	1.55	$7.90m	$94.75m	$20.87m	$73.89m
Indiana	476,862	0.483	$4,170	$4.4	$1.16m	$13.91m	1,907,446	1.93	$4.64m	$55.64m	$10.86m	$44.78m
Kansas	274,063	0.568	$2,538	$6.0	$0.65m	$7.83m	3,523,030	7.30	$2.61m	$31.31m	$6.93m	$24.38m
Kentucky	144,620	0.220	$5,116	$9.7	$0.85m	$10.25m	578,480	0.88	$3.42m	$41.01m	$7.74m	$33.27m
Louisiana	308,810	0.482	$8,665	$3.3	$0.55m	$6.55m	1,235,240	1.93	$2.18m	$26.20m	$4.67m	$21.53m
Massachussets	282,630	0.322	$3,016	$4.7	$0.78m	$9.41m	1,130,518	1.29	$3.14m	$37.64m	$8.00m	$29.64m
Maryland	189,650	0.214	$13,338	$3.3	$0.28m	$3.36m	758,600	0.86	$1.12m	$13.44m	$2.32m	$11.12m
Maine	197,625	1.138	$1,105	$2.5	$0.17m	$2.03m	790,500	4.55	$0.68m	$8.12m	$2.52m	$5.60m
Michigan	994,769	0.745	$1,613	$3.9	$0.71m	$8.57m	3,979,076	2.98	$2.86m	$34.29m	$9.09m	$25.20m
Minnesota	469,183	0.593	$2,965	$3.7	$0.89m	$10.71m	1,876,730	2.37	$3.57m	$42.84m	$9.07m	$33.77m
Missouri	479,569	0.554	$2,236	$9.1	$1.02m	$12.21m	1,918,276	2.22	$4.07m	$48.83m	$11.28m	$37.55m
Mississippi	133,012	0.269	$4,270	$5.1	$0.51m	$6.10m	532,048	1.08	$2.03m	$24.39m	$4.88m	$19.52m
Montana	74,162	0.509	$1,012	$8.1	$0.23m	$2.77m	296,648	2.03	$0.92m	$11.07m	$3.77m	$7.30m
North Carolina	399,600	0.272	$12,955	$4.3	$1.43m	$17.10m	1,598,400	1.09	$5.70m	$68.40m	$11.76m	$56.65m
North Dakota	57,170	0.500	$1,474	$11.5	$0.21m	$2.56m	228,680	2.00	$0.85m	$10.26m	$2.80m	$7.46m
Nebraska	162,290	0.529	$1,518	$6.8	$0.33m	$3.99m	649,160	2.12	$1.33m	$15.95m	$4.19m	$11.76m

		Current Internet Access Costs					Meeting peaks					
State	Total Bandwidth (Mbps)	Bandwidth per Student (Mbps)	Average Monthly cost	Avg. Monthly cost per Mbps	Total Monthly Cost	Total Annual Cost	Estimated peak demand (4x bandwidth) - Mbps	Peak demand per student (Mbps)	Monthly cost to meet peaks with internet alone.	Annual cost to meet peaks with bandwidth	Annual cost to meet peaks with caching	Caching saving over bandwidth
New Hampshire	91,037	0.516	$1,695	$6.2	$0.20m	$2.40m	364,146	2.07	$0.80m	$9.60m	$2.62m	$6.97m
New Jersey	614,190	0.479	$3,053	$5.7	$1.44m	$17.29m	2,456,758	1.92	$5.76m	$69.17m	$14.74m	$54.43m
New Mexico	114,064	0.365	$4,695	$10.0	$0.38m	$4.62m	456,254	1.46	$1.54m	$18.48m	$3.56m	$14.92m
Nevada	130,853	0.305	$6,484	$1.8	$0.06m	$0.78m	523,410	1.22	$0.26m	$3.11m	$0.61m	$2.50m
New York	927,650	0.359	$2,212	$3.0	$1.40m	$16.80m	3,710,600	1.44	$5.60m	$67.22m	$15.34m	$51.88m
Ohio	928,911	0.578	$2,872	$5.3	$1.68m	$20.16m	3,715,644	2.31	$6.72m	$80.64m	$17.01m	$63.63m
Oklahoma	469,454	0.720	$2,799	$7.9	$1.29m	$15.45m	1,877,815	2.88	$5.15m	$61.81m	$13.32m	$48.48m
Oregon	325,010	0.595	$2,330	$8.9	$0.31m	$3.77m	1,300,040	2.38	$1.26m	$15.10m	$3.61m	$11.48m
Pennsylvania	1,274,775	0.799	$2,385	$2.3	$1.12m	$13.42m	5,099,100	3.19	$4.47m	$53.69m	$11.94m	$41.75m
Rhode Island	35,255	0.267	$5,777	$8.9	$0.18m	$2.22m	141,018	1.07	$0.74m	$8.87m	$1.66m	$7.21m
South Carolina	164,872	0.227	$2,975	$2.6	$0.24m	$2.93m	659,486	0.91	$0.98m	$11.71m	$2.44m	$9.27m
South Dakota	102,862	0.772	$1,861	$6.5	$0.25m	$3.04m	411,446	3.09	$1.01m	$12.15m	$2.95m	$9.20m
Tennessee	323,200	0.341	$12,919	$8.8	$1.72m	$20.62m	1,292,800	1.36	$6.87m	$82.48m	$14.20m	$68.28m
Texas	2,031,569	0.405	$4,241	$13.1	$4.25m	$51.04m	8,126,277	1.62	$17.01m	$204.15m	$39.60m	$164.56m
Utah	230,000	0.404	$14,191	$3.1	$0.51m	$6.13m	920,000	1.62	$2.04m	$24.52m	$4.21m	$20.31m
Virginia	373,928	0.295	$6,797	$5.0	$0.82m	$9.79m	1,890,532	1.49	$4.78m	$57.38m	$7.17m	$50.21m
Vermont	79,666	0.993	$3,020	$5.8	$0.16m	$1.92m	318,664	3.97	$0.64m	$7.68m	$1.61m	$6.08m
Washington	411,676	0.382	$2,386	$6.8	$0.66m	$7.87m	1,646,704	1.53	$2.62m	$31.50m	$7.03m	$24.47m
Wisconsin	544,292	0.664	$2,275	$3.6	$0.77m	$9.28m	2,177,167	2.65	$3.09m	$37.13m	$8.77m	$28.36m
West Virginia	98,705	0.356	$7,595	$4.5	$0.38m	$4.56m	394,820	1.42	$1.52m	$18.23m	$3.29m	$14.93m
Wyoming	58,910	0.638	$4,375	$10.5	$0.19m	$2.26m	235,640	2.55	$0.75m	$9.03m	$1.77m	$7.26m
TOTAL	**20,956,050**	**0.48**	**$14,033**	**$26.65**	**$46.6m**	**$559.7m**	**86,645,796**	**2.03**	**$188.09m**	**$2,257.03m**	**$447.89m**	**$1,809.14m**